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Effect of Fly Ash on the Photosynthetic Parameters of *Zizyphus Mauritiana*

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Abstract

The present work was conducted in the vicinity of a coal fired thermal power plant (NTPC, Sipat, Bilaspur. The soil was analysed for speciation of heavy metals present in it due to contamination by fly ash emitted from thermal power plant. Heavy metals were estimated using atomic absorption spectrophotometer for Fe, Zn, Pb, Cd, Mo, Cu, Cr, Co, V and Ni and the standard solution was prepared using standard metal solution of Inorganic Ventures. Fe was present in maximum concentration and Cd in minimum concentration while Mo was absent. The effects of these metals presented in the soil on various photosynthetic parameters (fluorescence, Fv/Fm, fluorescence quenching coefficients, relative electron transport rate, photosynthetic active radiation, ETR-Factor absorptance of photons by photosynthetic pigments etc.) of *Zizyphus mauritiana* were estimated. The observed value of Fv/Fm (indication of the maximum and effective photochemical quantum yield of PS II) for *Zizyphus mauritiana* was 0.53. The heavy metals presented in the soil have negative effects on *Zizyphus mauritiana* because a healthy plant Fv/Fm should not be less than 0.75. Similarly other parameters were also adversely affected by the presence of heavy metals. The reduction in yield of photosystem II due to presence of metals will ultimately lead to overall reduction in the plant growth and its productivity and ultimately ecosystem productivity. The presence of metals is also harmful for the humans as it will enter into their bodies through food chain. Therefore, the issue of fly ash emitted from thermal power plants needs to be addressed in a proper way so as to avoid the contamination of soil surrounding to the power plant.

Keywords

Heavy Metals; Fluorescence; ETR-Factor; Fv/Fm; Photosystem II; Zizyphus Mauritiana

Introduction

Environmental pollution in recent years has increases manifolds due to rapid growth of industries and anthropogenic pressure worldwide. Heavy metal pollution due to thermal power plant, mining and other industries is of serious concern to the environmentalists since they persist in the environment for generations and may cause serious problems to the biotic world. There are various sources of heavy metal coming in the environment such as mining industries, electroplating industries, thermal power plants, textile, and leather and tanning industries etc. Out of these industries fly ash coming from thermal power plants is an important source of heavy metals to the environment. Huge amount of fly ash is generated in India from the coal fired thermal power plants leading to environmental pollution (TERI, 2000). The fly ash contains several heavy metals such as As, Mo, Se, Cd and Zn (el-Mogazi et al., 1988). Presence of these metals and other components may make the fly ash toxic which may have adverse impacts on flora and fauna of the ecosystems particularly in the surroundings of power plants. Environmentally released metals are mainly deposited in soils and are mobilized either by leaching or by uptake into plants (Prajapati., 2012; Meravi & Prajapati., 2014).

Various researches have been established that there is a clear cut relationship between the exposure of heavy metals and the physiological responses in plants such as changes in chlorophyll content and photosynthesis activities. Usually metals exposure of low levels does not lead to any visible effects on the plants, but it is only after a threshold limit of metals (Rodríguez et al., 2007). Fly ash contaminated by metals causes stresses that limit plant growth and development (Liphadzi & Kirkham, 2006). Studies have shown that plant species growing in polluted environments may be stressed in various ways and viz. bioaccumulation of metals to toxic concentrations may disturb normal physiological processes of plants (Dahmani-Muller et al., 2000; Monni et al., 2001; Plekhanov & Chemeris, 2003; Liphadzi & Kirkham, 2006). For example, studies have shown that growth and photosynthetic

activities are adversely affected by cadmium (Nagel et al., 1996). However, metal pollution of plants growing in the polluted environments may exhibit toxicity simultaneously and interactively at different levels (Walker et al., 2003; Vázquez et al., 2006; Rodríguez et al., 2007). The study conducted by various researchers shows that fly ash contaminated soil may adversely affect the photosynthetic rate and ultimately the plant (Sharma and Kalra, 2006)

Materials and Methods

Present experiments was undertaken in the vicinity of a super thermal power plant (NTPC, Sipat, Chhattisgarh, India) located at 22°07′ N and 82°16′ 43 E with an installed capacity of 2980 MW. *Zizyphus mauritiana* Lam. growing in the area was selected for the present study. Analysis of soil contaminated by fly ash for heavy metals (Fe, Zn, Pb, Cd, Mo, Cu, Cr, Co and Ni) were performed with the help of atomic absorption spectrophotometer (AAS) model: AA 7000, SHIMADZU. The standards were prepared using standard metal solution of Inorganic Ventures. Photosynthetic parameters such as fluorescence, Fv/Fm, fluorescence quenching coefficients, relative electron transport rate, photosynthetic active radiation, ETR-Factor absorptance of photons by photosynthetic pigments etc. were measured using JUNIOR-PAM, Chlorophyll Fluorometer, Heinz Walz GmbH, Germany in the field condition. Composite sampling was performed from the surrounding of plant. The soil was dried in hot air oven for till soil weight became constant. 100 g oven dried soil was digested overnight in the *aqua regia* for dissolving the metals present in the soil. The solution was filtered by filter paper Whatman no 44 so as to remove fine particles.

Results and Discussions

Fly ash contaminates the soil adjoining to the power plants mainly by two ways. First, due to emissions from the power plant and second, from the re-suspension of fly ash present in the fly ash dykes because of various atmospheric phenomenon. The soil samples were taken from adjoining areas of the experimental plants for the analysis of heavy metals and metalloids by AAS. The analysis of soil sample showed the presence of various heavy metals and metalloids in different concentration as shown by table 1. It is clear from the table that Fe was present in maximum amount while Cd was present in minimum amount. Molybdenum was not detected by the AAS. Presence of these contaminants in soil will alter the physical and chemical properties of the soil that may have adverse effect on the biological communities of the soil.

TABLE 1: HEAVY METALS CONCENTRATION OF SOIL CONTAMINATED WITH FLY ASH (IN μG G^{-1} DRY WT. OF SOIL)

Metals	Fe	Zn	Pb	Cd	Mo	Cu	Cr	Co	Ni	V
Concentration	34.2	4.6	2.8	0.05	n.d.	2.6	1.2	1	0.1	3.9

Presence of these metals in soil may have adverse effect on the various physiological processes of *Zizyphus mauritiana* including the photosynthetic parameters in long run because of bioaccumulation of these metals inside the plant body. Fly ash deposited on plant leaf surfaces may impede with gas diffusion between the leaf and atmosphere. Sedimentation of dust particles affects the upper surfaces of leaves more (Thompson et al., 1984; Kim et al., 2000) while finer particles affects lower surfaces (Ricks and Williams 1974; Krajickova and Mejstrik, 1984; Fowler et al., 1989; Beckett at al. 2000). The adverse effects of metals on the various photosynthetic parameters which may be due to deposition of fly ash containing heavy metals o the leaves and in the stomata leading to bloackade of gaseous exchange is shown in the table 2. The Fv/Fm value which is an indication of the maximum and effective photochemical quantum yield of PS II (Schreiber and Bilger 1993) is below 0.75. If the value of Fv/Fm is below 0.75 (0.543, 0.528 and 0.519 in present study), it means that the plant is under stressed condition and accordingly other photosynthetic parameters are also adversely affected. Fly ash deposition affects the light available for photosynthesis and blocks the stomatal pore for diffusion of gases and thus puts stress on plant metabolism (Eller, 1977; Hope et al., 1991; Keller and Lamprecht, 1995; Anthony, 2001).

Some metals such as Cu, Zn, Co, Fe in trace amounts are essential for various metabolic activities of plants. But excess of all kinds of metals adversely affect the plant metabolism (Hall, 2002). In plants, metals exert their toxic action mostly by damaging chloroplast and disturbing photosynthesis. The inhibition of photosynthesis is the consequence and interference of metal ions with photosynthetic enzymes and chloroplast membranes. These heavy metals may be translocated to various aboveground parts of the plants through water uptake by the plants and may accumulate in fruits leading to degradation of its quality. The ETR-F values correspond to the ratio of photons absorbed by photo-synthetic pigments to incident photons which is 0.84 in present case. The PAR value in present

case is 429 (in µmoles/(m^2·s) and the relative electron transport rate (ETR) varies during the experiments which are provided in the table 2. Variation of other photosynthetic parameters can also be observed from the given table 2.

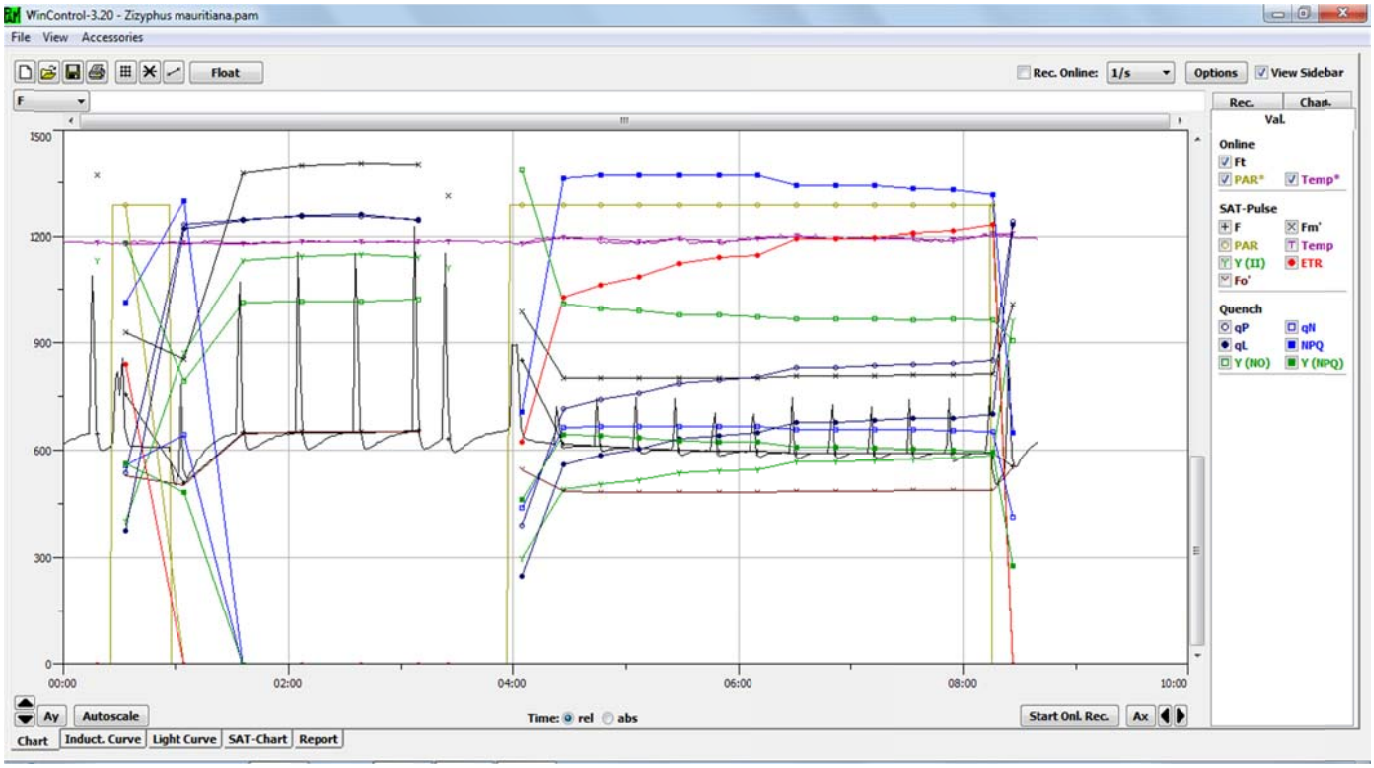

FIGURE 1. PRINT SCREEN VIEW OF VARIOUS PHOTOSYSNTHETIC PARAMETERS (OF *ZIZYPHUS MAURITIANA*) IN SOIL CONTAMINATED BY HEAVY METALS AND METALLOIDS

TABLE 2: THE DETAILED REPORT OF THE VARIOUS PHOTOSYSNTHETIC PARAMETERS (*ZIZYPHUS MAURITIANA*)

08-01-2015	09:43:34	WinControl (rev 700) report file																		
Date	Time	Type	No.	1:F	1:Fm'	1:PAR	1:Temp	1:Y (II)	1:ETR	1:Fo'	1:ETR-F.	1:qP	1:qN	1:qL	1:NPQ	1:Y (NO)	1:Y (NPQ)	1:Fo	1:Fm	1:Fv/Fm
		D		Device Nr: #1, Mini-PAM																
15-08-2013	12:42:51	SCHS		Chart Start																
15-08-2013	12:43:03	FO	11	647	1415	0	31.6	0.543	0	-	0.84	-	-	-	-	-	-	647	1415	0.543
15-08-2013	12:43:55	F	12	616	795	429	31.5	0.225	40.5	~477	0.84	0.563	0.586	0.436	0.78	0.435	0.34	647	1415	0.543
15-08-2013	12:45:32	F	13	608	791	429	31.4	0.231	41.6	~475	0.84	0.579	0.589	0.452	0.789	0.43	0.339	647	1415	0.543
15-08-2013	12:45:49	SCHS		Chart start																
15-08-2013	12:46:07	FO	14	646	1370	0	31.5	0.528	0	-	0.84	-	-	-	-	-	-	646	1370	0.528
15-08-2013	12:46:22	F	15	757	930	429	31.4	0.186	33.5	~528	0.84	0.43	0.445	0.3	0.473	0.552	0.262	646	1370	0.528
15-08-2013	12:46:53	F	16	507	853	0	31.5	0.406	0	~502	0.84	0.986	0.515	0.976	0.606	0.37	0.224	646	1370	0.528
15-08-2013	12:47:25	F	17	649	1376	0	31.4	0.528	0	~647	0.84	0.997	-0.007	0.994	-0.004	0.473	-0.001	646	1370	0.528
15-08-2013	12:47:55	F	18	650	1396	0	31.6	0.534	0	~652	0.84	1.003	-0.028	1.006	-0.019	0.474	-0.008	646	1370	0.528
15-08-2013	12:48:28	F	19	650	1404	0	31.6	0.537	0	~653	0.84	1.004	-0.037	1.009	-0.024	0.474	-0.011	646	1370	0.528
15-08-2013	12:48:58	F	20	655	1400	0	31.6	0.532	0	~653	0.84	0.997	-0.032	0.994	-0.021	0.477	-0.009	646	1370	0.528
15-08-2013	12:49:10	SICS		Induction Curve start																
15-08-2013	12:49:14	FO	21	631	1312	0	31.6	0.519	0	-	0.84	-	-	-	-	-	-	631	1312	0.519
15-08-2013	12:49:53	F	22	849	986	429	31.4	0.139	25	~544	0.84	0.31	0.351	0.199	0.331	0.646	0.215	631	1312	0.519
15-08-2013	12:50:15	F	23	619	802	429	31.9	0.228	41.1	~483	0.84	0.574	0.532	0.448	0.636	0.471	0.301	631	1312	0.519
15-08-2013	12:50:35	F	24	611	800	429	31.8	0.236	42.5	~482	0.84	0.594	0.533	0.469	0.64	0.465	0.299	631	1312	0.519
15-08-2013	12:50:56	F	25	607	800	429	31.6	0.241	43.4	~482	0.84	0.607	0.533	0.482	0.64	0.462	0.297	631	1312	0.519
15-08-2013	12:51:17	F	26	600	800	429	31.8	0.25	45	~482	0.84	0.629	0.533	0.505	0.64	0.457	0.293	631	1312	0.519
15-08-2013	12:51:38	F	27	598	800	429	31.6	0.253	45.6	~482	0.84	0.635	0.533	0.512	0.64	0.456	0.291	631	1312	0.519
15-08-2013	12:51:59	F	28	596	800	429	31.8	0.255	45.9	~482	0.84	0.642	0.533	0.519	0.64	0.454	0.291	631	1312	0.519
15-08-2013	12:52:19	F	29	593	807	429	32	0.265	47.7	~485	0.84	0.665	0.527	0.544	0.626	0.451	0.284	631	1312	0.519
15-08-2013	12:52:40	F	30	593	807	429	31.8	0.265	47.7	~485	0.84	0.665	0.527	0.544	0.626	0.451	0.284	631	1312	0.519
15-08-2013	12:53:01	F	31	592	807	429	31.8	0.266	47.9	~485	0.84	0.668	0.527	0.547	0.626	0.451	0.283	631	1312	0.519
15-08-2013	12:53:22	F	32	592	809	429	31.8	0.268	48.3	~486	0.84	0.672	0.526	0.552	0.622	0.45	0.282	631	1312	0.519
15-08-2013	12:53:43	F	33	592	810	429	31.7	0.269	48.5	~486	0.84	0.673	0.524	0.552	0.62	0.451	0.28	631	1312	0.519
15-08-2013	12:54:04	F	34	591	813	429	32.1	0.273	49.2	~487	0.84	0.681	0.521	0.561	0.614	0.45	0.277	631	1312	0.519
15-08-2013	12:54:15	F	35	555	1007	0	32.1	0.449	0	~551	0.84	0.991	0.33	0.984	0.303	0.422	0.129	631	1312	0.519

Acronyms for table 2
F_o Basic fluorescence yield (relative units) recorded with low measuring light intensities.
F_m Maximal chlorophyll fluorescence yield when photosystem II reaction centers are closed by a strong light pulse (relative units).
$F_v/F_m = (F_m-F_o)/F_m$ maximum photochemical quantum yield of photosystem II.
qP and qL Coefficients of photochemical fluorescence quenching
qN and **NPQ** Parameters of non-photochemical quenching
Y(NO) and Y(NPQ) Yields of non-photochemical quenching
PAR Photosynthetic active radiation
ETR Relative electron transport rate
ETR-Factor Absorptance of photons by photosynthetic pigments

Conclusions

The present study was conducted in the vicinity of a coal fired thermal power plant so as to ensure whether the fly ash emitted from the thermal power plants have the capacity to contaminate the soil by heavy metals or not. The analysis showed that soil was moderately contaminated by the presence of several metals because of fly ash emitted from coal fired thermal power plant. At the same time, the adverse effects of these metals and metalloids on the various photosynthetic parameters of the *Zizyphus mauritiana* were also studied. The study indicated that presence of heavy metals had negative effects on photosynthetic parameters that would ultimately lead to reduction in the net productivity of the plants and ultimately the ecosystem. Therefore it can be concluded from the present study that fly ash emitted from coal fired thermal power plants contaminates the soil of the adjoining areas. Henceforth, the issue of fly ash emitted from coal fired thermal power plants needs to be addressed seriously using modern day emission control technologies in order to minimise the adverse effects of fly ash on ecosystem productivity.

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